programa final

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IBGE 60 anos
1936-1996

Uma das maneiras de olhar o ofício de produzir informações sociais, econômicas e territoriais é como arte de descrever o mundo. Estatísticas e mapas transportam os fenômenos da realidade para escalas apropriadas à perspectiva de nossa visão humana e nos permitem pensar e agir à distância, construindo avenidas de mão dupla que juntam o mundo e suas imagens. Maior o poder de síntese dessas representações, combinando, com precisão, elementos dispersos e heterogêneos do cotidiano, maior o nosso conhecimento e a nossa capacidade de compreender e transformar a realidade.

Visto como arte, o ofício de produzir essas informações reflete a cultura de um País e de sua época, como essa cultura vê o mundo e o torna visível, redefinindo o que vê e o que há para se ver.

No cenário de contínua inovação tecnológica e mudança de culturas da sociedade contemporânea, as novas tecnologias de informação - reunindo computadores, telecomunicações e redes de informação - aceleram aquele movimento de mobilização do mundo real. Aumenta a velocidade da acumulação de informação e são ampliados seus requisitos de atualização, formato - mais flexível, personalizado e interativo - e, principalmente, de acessibilidade. A plataforma digital vem se consolidando como o meio mais simples, barato e poderoso para tratar a informação, tornando possíveis novos produtos e serviços e conquistando novos usuários.

Acreditamos ser o ambiente de conversa e controvérsia e de troca entre as diferentes disciplinas, nas mesas redondas e sessões temáticas das Conferências Nacionais de Geografia, Cartografia e Estatística e do Simpósio de Inovações, aquele que melhor enseja o aprimoramento do consenso sobre os fenômenos a serem mensurados para retratar a sociedade, a economia e o território nacional e sobre as prioridades e formatos das informações necessárias para o fortalecimento da cidadania, a definição de políticas públicas e a gestão político - administrativa do País, e para criar uma sociedade mais justa.

Simon Schwartzman
Coordenador Geral do ENCONTRO

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Registramos ainda a colaboração de técnicos das diferentes áreas do IBGE, com seu trabalho, críticas e sugestões para a consolidação do projeto do ENCONTRO.

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GIS applications in official statistics – the Swiss experience

by

Rainer Humbel
Swiss Federal Statistical Office
Spatial Data Section
CH-3003 Bern
phone: 0041 31 322 86 91
fax: 0041 31 992 05 62
e-mail: rainer.humbel@bfs.admin.ch

Abstract

According to the modern Swiss federal statistics law, practically all data generally contained in and analyzed with geographic information systems (such as data on points or areas of land, on persons or economic entities to which a geographic location can be associated) are considered statistical data. The Swiss Federal Statistical Office generates a variety of results of this type, but many other government as well as private, semi-private and research institutions contribute considerably to the wealth of data already available. GIS technology is essential to administer and analyze this type of data efficiently and to present it comprehensibly considering its contextual and spatial complexity.

The Spatial Data Section of the Swiss Federal Statistical Office maintains with its GIS infrastructure a specialized user service which concentrates on data diffusion, advice and information in this field. Its GEOSTAT project concentrates on a federal GIS database of geocoded, spatially relevant data sets from various, mostly governmental sources. The section's geocoding service assigns coordinates to all residential buildings registered in the country's census of population and housing as well as the locations of business activities of the census of business and enterprises. This allows to integrate a variety of standard variables from both censuses at a spatial resolution of 1 ha within its GIS. Such spatial statistical data of a fine resolution provides a wealth of information for regional data analysis and presentation which may be used in a flexible and versatile way for a multitude of applications such as planning, mapping, visualization etc.

The official Swiss land use statistics constitutes another activity of the section and is one of the principal GIS users as well as an important data supplier. GIS data and methods are intensively used to streamline and calibrate the ongoing updating cycle 1992/97. Different plotter maps assist the stereoscopic photo interpretation by providing additional information not easily visible from the used aerial photographs. The preliminary results after interpretation and verification undergo a series of automated tests, many of which are based on a multitude of spatial GIS data.

Keywords

Geographic information system, spatial and statistical data analysis, data presentation and dissemination, GEOSTAT, census, land use statistics and mapping, geocoding statistics

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1 Geographical information systems and the legal basis of Swiss national statistics

Under the term *geographical information system* (GIS) we understand, according to a recently published definition by the GIS working group of the Swiss Informatics Conference [1], an information system containing geographical or spatially referenced data, mainly on the atmosphere, the earth's surface (vegetation, land use), the soil and the lithosphere, including its technical and administrative infrastructure as well as its economical and ecological framework. A GIS facilitates systematic data capture and storage, actualization or updating, processing, analysis and combination of such data on the basis of a common spatial reference system. Offering these capabilities, geographical information systems are destined to support the decision finding process in administration, jurisdiction and economy as well as for many spatially relevant planning endeavors.

In Switzerland, the objectives and scope of the Federal Statistical Office and the entire official statistics on the national level are defined and legally delimited by a federal statistical law effective since August 1993. Its third and fourth articles mention land use and spatial data as relevant and legitimate federal statistical information. According to the official message of the Swiss Federal Council accompanying this law, statistical data includes, among other, information on persons, households, enterprises, but also on land parcels, buildings, apartments, hectares and spatially defined points as well as on spatially referenced administrative areas and other perimeters. We can conclude from this that practically all data generally kept and analyzed in geographical information systems can be considered to be statistical or statistically relevant.

2 Swiss Federal Statistical Office: organizational structure and spatial statistics

The Swiss Federal Statistical Office which is one of the government departments under the Swiss Ministry of the Interior consists of five divisions and altogether 22 sections (Fig. 1). Besides of the *Central Services Division* the four so-called technical divisions concentrate on the different fields covered by Swiss official statistics. The *Population and Employment Division* is in charge of the statistics on population and household structure, population development (demography), health and employment. It is also responsible for the *national census of population and housing*, which is conducted every ten years. The *Economics and Prices Division* publishes the Swiss national accounts, prices and cost of living indexes, statistics on production, economic activities and business turnover, wages, salaries, working conditions etc. The statistics of the *Society and Education Division* cover culture, politics, elections, schools and other teaching institutions, research and development, and jurisdiction and crime. The sections and service of the *Spatial Economics Division* provide information in a spatial or geographical context, on environment, tourism, traffic and transportation, and agriculture and forestry. The last two divisions also share the responsibility for the national censuses of business and enterprises. The *Spatial Data Section* had its origin with the launch of a extensive statistical investigation on land utilization in Switzerland, but has meanwhile extended its scope and activities beyond the single aspect of land use to encompass a multitude of data and information that are available or need to be analyzed within a specific geographic or spatial context. The publication and regular updating of the official Swiss land use statistics still makes up one of the major projects of the section, while another one is the comprehensive geographic data bank of GEOSTAT. With GEOSTAT, the Spatial Data Section also operates one of the first and well established geographical information systems within the Swiss federal administration.

With the framework of the federal law on statistics in mind, it is only consequent that the Federal Statistical Office tries since many years to assemble a solid base of geo-referenced (GIS) data, to explore the capabilities and potential of available geographical information systems for the management, analysis, presentation and diffusion of GIS data, and to satisfy the needs of a wide range of interested data users and derived products and results. In order to reap the full benefits offered by GIS it is, with the presently available and installed technology, inevitable to bring together and centrally combine the variety of relevant geo-referenced statistical data which is, however, usually generated or digitized decentrally by different organizations and institutions. A national statistical office is expected to serve as an optimal location for a general data repository attracting the collaboration of data producers by offering them technical and marketing advice and by relieving them of administrative and legal overheads necessary for a professional and user-oriented dissemination of their data.

This approach, on the other hand, offers the unique possibility to data users to obtain data combinations and results of analyses involving several independent data sets rather than being forced to assemble each and every required information from its own source and invest in the infrastructure, skill and time to perform every required analysis on his own.

3 GEOSTAT

3.1 Background

With the transfer of a Swiss geographical database for regional planning purposes from the Department of Planning of the Federal Institute of Technology of Zurich in 1976, the Federal Statistical Office did the first step towards the establishment of geo-referenced statistics independent of the traditionally used administrative boundaries. Since then, the information content of this grid or raster system was systematically expanded and enhanced and the data was disseminated to an ever growing group of interested data users from various fields of research, education and administration. Increasing amounts of data, largely widened and multiplied data needs and requests, and technological advancements in computer hard- and software and data processing methods made a complete redefinition of the project and an infrastructural refurbishment mandatory. In connection with the considerable data management tasks for the new Swiss land use statistics, the installation of a geographic information system was extensively evaluated and finally decided on. Based on a specific analysis of users needs, a formal concept report, as well as a survey among producers and owners of geo-referenced data within the federal administration, the Swiss Interior Ministry finally decided in 1987 to formally establish the new project GEOSTAT. Presently, the GEOSTAT GIS does not only contain raster and point data with a resolution of 1 ha but also several vector data sets. The installation of an efficient, modern GIS and the hardware upgrades and extensions of the past years now allow GEOSTAT to prepare analyses of combined data sets efficiently and fast.

3.2 Objectives

The main targets and objectives of GEOSTAT did hardly change since the formulation of the original project concept in 1987:

- Integration, administration and maintenance of different geocoded, spatially relevant data available with the Swiss federal administration. For this data, coverage of the entire country and a spatial resolution of 100 m, resp. a map scale of 1:25'000 are envisaged.
- Providing access to various available geo-referenced data for a wide potential user community from the fields of administration, education, research, economy and others and delivering them the desired data subsets and combinations.
- Processing and analysis of available data according to the specific requirements of users, as well as advice and support of users for their own analyses and projects.
- Cooperation with researchers and interested institutions to develop and test analysis methods and processing algorithms.
- Coordination, guidance and help for data collection, digitization and utilization as well as for the establishment of individual GIS infrastructure, in regard to data formats, methodical aspects and later analysis, especially for federal government institutions.

3.3 Organization and working principles

GEOSTAT consists, besides of the project management, of two groups. The *data processing group* is responsible for maintaining and building up the system including programming, data integration, consistency and quality control.

The *user service group* controls the flow of data to and from GEOSTAT (Fig. 2). Therefore, contacts are maintained with data owners and users, aiming at an institutionalized interchange of information on existing spatial data and information systems (user manual, national catalogues of GIS data and systems). The user service group is responsible for data exchange, and answers all kinds of telephone and mail inquiries. Its main task is to provide expert inquiry services. Potential users are advised and supported in selecting suitable data, defining transfer modes and data formats for successful data exchange, and identifying meaningful data combination possibilities.

Data owners—persons or institutions possessing copyright on spatially referenced data—are approached by GEOSTAT in order to negotiate the integration, utilization and dissemination of their data. Data is released to GEOSTAT by the specialists concerned, who are responsible for its accuracy, validity, definition and updating and who decide on the specific conditions or eventual restrictions for the use of their data.

GEOSTAT attempts to promote a coordinated collection and compilation of spatial data throughout Switzerland. This should avoid as far as possible parallel and inefficient efforts for data collection and administration, both within and outside of the federal administration.

3.4 GEOSTAT data

Today, GEOSTAT has reached a mature state and offers a basic complement of the most essential GIS data sets in high demand. The presently available data cover multi-purpose needs of a majority of users and can serve to most of them as sufficient input for compiling reasonably detailed and diversified base maps, upon which they can easily assemble their own, specific, specialized thematic data layers. In addition, the data allows a multitude of interesting and challenging analyses to the user communities in federal, cantonal and local administration, in research and education as well as to a large number of private consultancy companies in the fields of planning, environmental issues, agriculture, sociology etc.

Table 1 provides an overview over the presently available data sets with their most important characteristics which are all described in detail in GEOSTAT's ample user manual. The manual is periodically updated and is available in German or French, as well as a free, synoptic color brochure in four languages (German, French, Italian, English) through the Federal Statistical Office [2, 3].

3.5 Data presentation: traditional cartography and hectare grid data

GEOSTAT is a powerful instrument for supporting and developing the presentation of statistical data in cartographic form. Thematic cartography is a classic means for providing a rapid overview of statistical data in spatial terms, encouraging the comparison of structures and developments and the preparation of explanatory hypotheses. Traditionally, statistical data (absolute figures, percentages, variations, rates, means, etc.) are aggregated at territorial unit level (country, canton, district, commune, etc.). However, these territorial units are defined by political and administrative boundaries which often differ in size and importance. The representation of subtle structures and developments within territorial units and their links to the natural and physical environment (habitat, geology, topography, land use, flora and fauna, etc.) is still problematic.

Two solutions specific to geographical information systems make it possible to go beyond the limits of traditional cartography:

- the presentation of data by basic statistical units ("building block", survey sector, enumeration district or area, settlement, etc.)
- the presentation of statistical units according to their position in a grid (hectare, square kilometer, acre, e.g.).

Cartographic publishing presents grid cells according to selected units and features. All geocoded statistical information of Switzerland available with GEOSTAT can be presented within the framework of a hectare grid. The comparative advantage of the grid lies in the possibility of combining hectometric data with other geocoded information such as relief, the road network, public transport stops, social infrastructures (schools, homes, services), construction, industrial or protected zones etc., and to define arbitrary and flexible spatial aggregations specific to the problems investigated and accurate within the limits of the spatial resolution of the grid.

3.6 Data combinations: conflict potential between traffic routes and environment

A variety of geographic and environmental data available with GEOSTAT offers an interesting potential for the evaluation of possible conflicts between population, settlements or human infrastructure on one side and the environment or nature on the other. The following example may illustrate the scope and nature of such combined data analyses.

The federal inventory on landscapes and natural monuments of national importance describes approximately 120 objects which enjoy a certain legal protection. Their present characteristics are to be preserved and their exploitation or utilization restricted. Above all, they are considered unique from a Swiss or European point of view in regard to their beauty, landscape coverage, specific character, or scientific, ecological or cultural importance. A comparison with the existing network of Swiss national motorways already reveals many potential conflict areas (Fig. 3). Altogether, more than 60 km of motorways are intersecting these partly protected areas, threatening their visual beauty, areal integrity and exposing significant parts of them to pollution and noise emissions. Further implication of modern civilization on such areas could be analyzed by superimposing them with railway lines or populated areas of medium and high densities.

Table 1: Data sets in GEOSTAT

Data category, thematic	Data set	Data structure	Resolution or generalization level
Administration, Surveying	Administrative boundaries of Switzerland (communes, districts, cantons)	Polygons	1:25,000
	Generalized administrative boundaries	Polygons	≈ 1:300,000 ≈ 1:500,000 ≈ 1:1,000,000
Topography	DTM, height, slope, exposition; absolute and classified	Point or raster	Hectare
Geology, Soils	Simplified geotectonic map of Switzerland	Polygons	1:200,000
	Soil suitability map of Switzerland	Polygons	1:200,000
Hydrology, water resources	Swiss lakes	Polygons	1:25,000
	Swiss rivers and streams	Lines	1:200,000
Land cover, land use	Swiss land use statistics 1972	Polygons or raster	Hectare
	Swiss land use statistics 1979/85, 15 or 24 aggregated categories	Point or raster	Hectare
	Thematic background layers derived from the Swiss land use statistics 1979/85, 3 levels of generalization, 17 aggregated categories	Raster	Hectare
Population, buildings	Swiss census of population 1970 (3 variables, classified results, 750 communes, approximately 60 % of Swiss population)	Point or raster	Hectare
	Swiss census of population 1980 (54 variables, 620 communes, ≈ 50 % of Swiss population)	Point or raster	Hectare
	Swiss census of population 1990 (≈ 400 variables, entire country covered)	Point or raster	Hectare
Traffic *(under preparation)*	Main streets and motorways	Lines	≈ 1:50,000
	Railways and public transport lines	Lines	≈ 1:50,000
Planning	Legal construction zones (residential and industrial zones; approx. 1980)	Raster	Hectare
Protected areas, inventories	Federal inventory of landscapes and natural features of national importance (BLN)	Polygons	1:25,000
	Boundaries of the Swiss National Park (GR)	Polygons	1:25,000
	Federal inventory of bird reserves of international and national importance	Polygons	1:25,000
	Federal inventory of prohibited hunting areas	Polygons	1:25,000
	Federal inventory of upland and transitory moors of national importance	Polygons	1:25,000
	Federal inventory of lowland moors of national importance	Polygons	1:25,000
	Federal inventory of river meadows of national importance	Polygons	1:25,000

4 GIS – a mandatory tool for the Swiss land use statistics

4.1 Arealstatistik 1979/85, the official Swiss land use statistics

Since 1912, the Swiss Federal Statistical Office published four times official land use statistics for the entire area of Switzerland; for these statistics, the German term *Arealstatistik* has been coined. These efforts were, however, incomplete or burdened with methodical shortcomings. For many requirements, the number of land use categories distinguished was insufficient, and comparisons between the results of the different statistics could hardly be performed. In order to obtain a database to be regularly updated it was decided in 1982 to commission the Statistical Office to establish a new, much more detailed and accurate land use statistics. The method of visual, stereoscopic interpretation of regularly spaced sample points at 100 m distance each from the other geometrically adjusted to conventional black and white aerial photographs was found to be a good compromise between accuracy, costs, time and staff needed. The new Arealstatistik together with its periodic updates will provide every 6-12 years detailed information on the ongoing changes and transformation processes in the utilization of land in Switzerland.

After interpretation and verification, the land use codes (69 two-digit figures, each of which defines one of the basic land use categories) were manually entered into a computer. With the first series of interpreted aerial photographs it became soon obvious, that such data can only be managed and analyzed with a modern and powerful computer tool in an efficient and timely manner. Therefore, the land use statistics provided the first and strongest necessity to install a powerful and up-to-date, real GIS for the Spatial Data Section and GEOSTAT. It therefore was and still is the principal user of the GEOSTAT facility. On the other side, the Arealstatistik is an important supplier of GEOSTAT data as well, since its data is permanently integrated in the GIS database after a series of automatic verification and quality controlling steps (see also 4.3).

With the GEOSTAT GIS, this data can be analyzed according to any arbitrary perimeters (as long as these are available in digital form too), i.e. according to political and administrative units (as published), according to river catchment areas, to reserves or protection zones, to planning zones or to any areas digitally defined. The first land use statistics according to this new method was completed in 1992 and its results have been published in two table volumes [4, 5] and made available in digital form to the interested public. For these publications as well as for inclusion into the GIS of GEOSTAT and the dissemination of digital data, the 69 base categories are combined to standard aggregations of 12, 15 and 24 categories. By aggregating categories, the statistical error caused by the sample point method can be reduced and the validity of results and conclusions improved.

4.2 Data generalization: publication of a Land Use Map of Switzerland

As the 1979/85 land use statistics is based on the evaluation of sample points and not of areas, the direct reproduction of its results in the form of a comprehensive map raises problems. Statistically, each sample point does in fact represent one hectare of the surface area of Switzerland but its location reveals little about the location of the hectare put to the same use that it represents. Thus, a cartographic representation of the basic data as of the GEOSTAT standard aggregations with 24 or 15 kinds of land use results in an uneven, implausible map, in which many categories appear widely dispersed in an apparently almost arbitrary distribution. This applies particularly to linear and small-scale types of land use such as roads or buildings.

To obtain easily interpretable matrix or grid data as basis for a visually attractive map, the point data of the areal statistics have to be reclassified and generalized. For this purpose, a multi-step procedure was chosen. The first step consists of reducing and reallocating the 69 basic categories to the 17 new land use categories in the land use map. This reallocation gives a much "smoother" map on which, as intended, most of the linear and many of the small-scale uses (roads, rivers, free-standing buildings, etc.) are eliminated. Despite the resulting obvious generalization, this data still contains some 45,000 separate isolated grid cells, which are unsuitable for many applications, particularly for medium and small scale map representation. The aim in the next generalization steps was therefore to apply smoothing and image processing procedures so as to rearrange these isolated uses, bearing in mind their surroundings, in such a way that larger, contiguous and homogenous land use areas appeared.

The result of several such generalization steps forms the basis of a land use map on Switzerland published recently by the Federal Statistical Office [6]. To replace the linear categories lost through the generalization and to improve the legibility of the map, a vectorized road, rail and river network from the geographic information system of GEOSTAT was superimposed on the land use information. The names of towns with over 10,000 inhabitants (1990) and other clearly recognizable settlements in the land use pattern of the map provide further orientation guides.

4.3 GIS support for the new Arealstatistik 1992/97

After publication of the results of the first land use statistics established based on the new method (4.1), the Federal Statistical Office decided to immediately start a comprehensive revision and updating program. Actual land use data is established applying the same technique, slightly improved in a few details, based on new aerial photographs of the Federal Office of Topography which are to cover the entire area of Switzerland in six blocks from 1992 to 1997. Therefore, the results will provide a new, actual state of land utilization in Switzerland as well as an overview on land use changes and land transformation processes predominant within the last twelve years.

The potential of the available GIS installation is being used extensively in the process of the elaboration of the new land use statistics. Making use of the presently available GIS data and the technical capabilities of the system allows to improve the interpretation of changes in the land use as well as the quality of the original statistics through backward correction of errors. Different custom-prepared plotter maps are prepared covering the area of each topographic map sheet of Switzerland (1:25'000 map scale) and serve as interpretation aids. These include the delimitation of construction zones, moors and wetlands, and information on the amount of dwellings and the functional designations of residential buildings geocoded for the 1990 census. An example of such a plot displaying dwellings and their major utilization type is reproduced in Fig. 4. With the help of the categories "exclusively residential", "mainly residential, including agricultural buildings", and "predominantly non-residential" the differentiation of building areas in *residential areas, agricultural buildings and surroundings,* and *unspecified buildings and surroundings* is facilitated. The information on the number of dwellings or apartments in a building permits to distinguish between *one- and two-family houses* on one and *flats or apartment blocks* on the other side.

Manual data entry is now done on a workstation with a customized GIS application, providing a convenient user interface to access an optimal complement of functionality and avoiding the necessity for a later data transfer into the GIS. After the independent double data capture of all sample points with a change in land use or a correction to the original statistics, data entry errors (i.e. non-corresponding information between the two data sets) are resolved and the results directly accessible for analysis or visualization within the GIS.

Multitemporal land use data will be available in printed as well as digital form for the western part of Switzerland from 1996 onwards, supplementing the official land use base data from 1979–85 with an updated inventory twelve years later. In a preliminary investigation of a test area around Baden, land use was interpreted and compared based on aerial photographs from 1982 and 1988. Clear indications of intensification of agricultural cultivation as well as an increasing area occupied by settlements and constructed, artificial surfaces were revealed. Most notable is the rapid disappearance of small aggregates such as fruit trees, field thickets, hedges and brush, and wetlands. These not only characterize the landscape visually, but also possess a high ecological value in terms of flora and fauna and are especially desirable from the recreational point of view. The findings so far are obvious: many areas where small aggregates formerly existed have either become built up or are now utilized for intensive agricultural purposes such as arable fields, meadows or intensive fruit cultivation. Within only six years land use intensification has led to more than 12 percent decrease of the area covered with small aggregates in the study area (Fig. 5). The forthcoming new land use data will prove whether the same tendency can be identified for larger areas and in different parts of Switzerland as well.

4.4 GIS analysis to reveal errors and mistakes

For the purpose of detection of errors (due to wrong photo interpretation, mistakes in the data entry process, unclear distinction of categories on aerial photographs, illegible handwriting of category codes etc.) a series of computer-assisted tests were designed, ranging from fairly simple database operations to reasonably complex GIS data combinations and analyses. The tests are performed on a map sheet by map sheet basis, as the entire statistics is map sheet oriented for the purpose of internal organization. At present, from altogether 249 map sheets 1:25'000 covering the country, 91 are in different stages of work and another 42 have been processed completely (Fig. 6). The criteria for the identification of possible errors are the following:

1 Impossible codes	Code numbers not defined in the land use nomenclature
2 Incompatible communes	Certain land use categories are restricted to occur only in a limited number of communes (or cantons) which are known in advance. • *Brush forest in cantons without brush forest according to the Swiss national forest inventory* • *Alpine pastures in communes without alp register* • *Vineyards in communes without wine production* • *Motorways, airports, air fields, golf courts, glaciers in communes known to lack these categories*
3 Unlikely elevation	Many land use categories are unlikely or even impossible to occur above (or below) a certain elevation above sea level. • *Vineyards* and *orchards* above 800 m • *Field fruit trees* or *horticultural areas* above 1000 m • *Favorable arable land and meadows* above 1200 m • *Other arable land and meadows* above 1500 m • *Closed forest* above 2000 m • *Open forest, woods* and *brush forest* above 2200 m • *Motorway areas* above 1000 m • *Recreational areas and cemeteries* above 1500 m • *Flood protection infrastructure* and *water shore vegetation* above 1800 m • *Settlement and urban areas* (except paths and roads), *river shores* above 2000 m • *Alpine pastures* below 800 m • *Brush forest, avalanche protection infrastructure* below 1200 m • *Remote/steep alpine pastures and meadows, glacier, eternal snow* below 1500 m
4 Unlikely slope and exposition	Many land use categories are unlikely or even impossible to occur at slopes higher than a certain threshold or at specific expositions. • *Airports, airfields, lakes* on slopes steeper than 15% • *Favorable arable land and meadows; recreational areas and cemeteries* on slopes steeper than 30% • *Alpine pastures* on slopes steeper than 70% • *Vineyards* on slopes steeper than 15% and exposed to NW-N-NE
5 Inconsistency with auxiliary data sets	• All land use categories except *lakes* and *water shore vegetation* within lakes derived from the national topographic maps • All land use categories except *wetlands, unproductive grass and shrubs,* and *forest* within officially declared and protected moor (wetland) areas

6 Unlikely land use changes in the last 12 years	• "Eternal" *construction sites* • *Afforestations* within former forest areas • *Damaged forest land* on former non-forest areas • Newly established *flood* and *avalanche protection infrastructure, railway areas, woods on green traffic way environs*, and *glaciers and perennial snow fields* • Erroneously identified *forest clearings* and *forest damages* • Former *glaciers and perennial snow fields* now disappeared
7 New buildings within incompatible legal construction zones	• New *non-agricultural buildings* outside of legal construction zones • New *industrial buildings* outside of legal industrial zones

The result of this testing procedure is a list of sample points with possible erroneous land use interpretation, indicating the relevant test criteria for each such point with a code. All these points are then reviewed by two team members on the basis of all available additional information sources (old and new topographic map sheets, registers of alpine agricultural areas, results from agricultural censuses and statistics, interpretation aids described in 3.2 etc.). Points for which a reliable decision cannot be taken yet are, once again, re-interpreted with a stereoscope. Exceptionally difficult instances, where a univocal decision cannot be reached still, are considered to be inspected at the occasion of a regular field verification trip of the team.

5 Geocoding of census data

5.1 Swiss national census of population and housing 1990

Basic, comprehensive population data on Switzerland are provided by national censuses of population, buildings and dwellings which are organized by the Federal Statistical Office every ten years. Through an elaborate process of geocoding, geographic coordinates are assigned to residential buildings, transferred to the building record which also includes information about dwellings and to the computerized register of census data.

The relationship between buildings and dwellings and the census of persons and households is established by a unique and identical building number. Thus, determining the position of the building simultaneously pinpoints the dwellings, households and persons surveyed. In the 1990 census, geocoding of residential buildings was organized for the first time as a compulsory, full-scale effort, resulting in geo-referenced census data covering the entire country. Key information from the 1990 census is integrated with other data sets within the geographical information system of GEOSTAT the same uniform way for the whole of Switzerland.

Building coordinates are surveyed using various procedures, based on cadastral survey plans, local plans, national maps and building registers. The first step is to record and number the building's exact position. Each building is represented by a centroid point which must be located inside of its floor plan. Afterwards, each building is assigned hectometric coordinates according to its location in the hectare grid. Each grid square is identified by an eight-digit number, i.e. the national 100m coordinates of its bottom left-hand corner.

Up to 10 staff members of the Spatial Data Section were working for the geocoding of the national population census of 1990. The project started in 1989 and finished in spring 1993. The transfer of roughly 400 standard variables into the geographical information system of GEOSTAT allows now to analyze census data according to arbitrary spatial perimeters and to combine it with other data sets available with GEOSTAT, such as for example the land use types, the legal construction zones etc.

Geocoding or geo-referencing of the results of censuses and other statistical data collection endeavors is an essential prerequisite in order to provide the GIS data necessary for interesting analyses of statistics and for attractive presentation of regional results. The amount and diversity of geocoded census data offers new and exciting possibilities for interpretation and presentation. Fig. 7 may serve as an example for such, sometimes unusual ways to illustrate the urban area and the population density of a city.

5.2 Swiss national census of business and enterprises 1995/96

In the past years a considerable demand for digitization and geocoding of other information which so far was only available in analog form (usually as plans and maps) as well as for new statistical surveys was identified. In order to tackle such jobs fast and with a reliable and experienced team, the geocoding project was confirmed as a permanent service within the Spatial Data Section. The first major task for the team is the presently ongoing census of business and enterprises which envisages geocoding the relevant non-residential buildings as well.

In order to complement the existing database for spatial statistics with economic information, geocoding of the census of business and enterprises 1995/96 was decided for the first time on a compulsory basis covering the entire country. In earlier censuses, a few regions collaborated with the Federal Statistical Office voluntarily, so that a similar geocoding exercise could be undertaken. On this basis, sample evaluations and analyses could be undertaken, showing the potential to reveal new facts and trends on a small-scale, regional level (Fig. 8). For that purpose, in addition to the coordinates for the residential buildings available from the census of population and housing 1990, coordinates for all places of work (geographically separated and identifiable parts of companies and enterprises) and any relevant newly built houses since 1990 have to be established. This effort will include agricultural holdings as well as economic activities of the second and third sector. Knowing these coordinates, the census results can then be made available aggregated per hectare and a standard set of variables permanently integrated in GEOSTAT.

6 Conclusions

Geographical information systems are a favorite tool for planning and managing what we have agreed to call sustainable development. They permit a holistic approach to establishing models, analyzing and better comprehending complex relationships between populations, spatial mobility, production methods and the environment.

These systems permit to manage, analyze and visualize spatial and statistical data, but they can also support the generation of statistics. This includes assistance for an efficient and transparent organization of statistics, especially censuses, on one side, such as the delineation of enumeration areas or the identification of stratified geographic sample areas. On the other side, the potential of exploiting GIS data and GIS functionality in order to improve the quality, consistency and reliability of statistical results appears to be of special interest. The modern tool GIS offers the unique capability to analyze and compare a variety of independent but logically interrelated data in a fast and cost-effective way. Only such a tool permits to perform various plausibility and consistency checks at acceptable expenditure of capital and personal resources and therefore to exploit the broad variety of available data sources optimally.

Coordination of data generation, management and assessment, especially among different government institutions, is one of the more important functions of a “geography unit” of a national statistical office. GEOSTAT is trying to contribute to this task effectively, besides of just managing its database and GIS and providing data and advice to users. Duplicated efforts and thus wasted funds and resources could be minimized while on the other, data consistency, comparability and compatibility of different data sets or thematic layers within the GIS could be enforced. GEOSTAT is determined to encourage more and more data owners, not only federal, but also local authorities and even private enterprises, to make use of its services and permit the integration of their own data sets into the GEOSTAT data bank. The majority of time-consuming user interaction associated with data diffusion is then taken care of by the GEOSTAT user communication group, leaving just a small amount of very special esquires for the data owner.

The presentation of GIS data is fascinating, but it requires high-performance information technology resources. Moreover, it is important to realize that managing GIS calls for a high degree of professionalism and an in-depth knowledge of the data stock, recording methods, modeling and generalization procedures. However, once a GIS infrastructure and know-how is built up, its application for quality and consistency control of newly produced statistical data must highly be recommended. The additional costs involved appear minimal in comparison to the benefit for the reliability of the final results and thus for the statistical office on the whole.

Sources and references

This document is, to a large extent, based on and compiled from the following two previously prepared papers:

- ◆ Rainer Humbel, Swiss Federal Statistical Office: GIS applications in official statistics – National Report by the Swiss Federal Statistical Office. Paper prepared for the UN-ECE/CES Work Session on GIS, April 1996, Washington D.C., USA
- ◆ Rainer Humbel, Swiss Federal Statistical Office: Quality and consistency control in statistics through GIS analysis of spatial data. Paper prepared for the UN-ECE/CES Work Session on GIS, April 1996, Washington D.C., USA

[1] Schweizerische Informatikkonferenz, Arbeitsgruppe Geographische Informationssysteme: SIK-GIS Empfehlungen 1992. Bern, September 1992

[2] Bundesamt für Statistik: GEOSTAT – Benützerhandbuch / Manuel d'utilisateur. Bern, 1992

[3] Swiss Federal Statistical Office: GEOSTAT – The service for Spatial Data in the Swiss Federal Administration. Berne, 1994

[4] Bundesamt für Statistik / Office fédéral de la statistique: Die Bodennutzung der Schweiz / L'utilisation du sol en Suisse, Arealstatistik 1979/85 / Statistique de la superficie 1979/85, Resultate nach Gemeinden / Résultats par commune. Berne, 1992

[5] Bundesamt für Statistik: Die Bodennutzung der Schweiz, Arealstatistik 1979/85, Resultate nach Kantonen und Bezirken. Bern, 1993

Office fédéral de la statistique: L'utilisation du sol en Suisse, Statistique de la superficie 1979/85, Résultats par canton et district. Berne, 1993

Ufficio federale di statistica: L'utilizazzione del suolo in Svizzera, Statistica della superficie 1979/85, Resultati per cantoni e distretti. Berna, 1993

[6] Swiss Federal Statistical Office: Land use in Switzerland. Map at a scale of 1:300,000; texts in german, french, italien and english, Berne 1993

Fig. 1 Simplified organization chart of the Swiss Federal Statistical Office

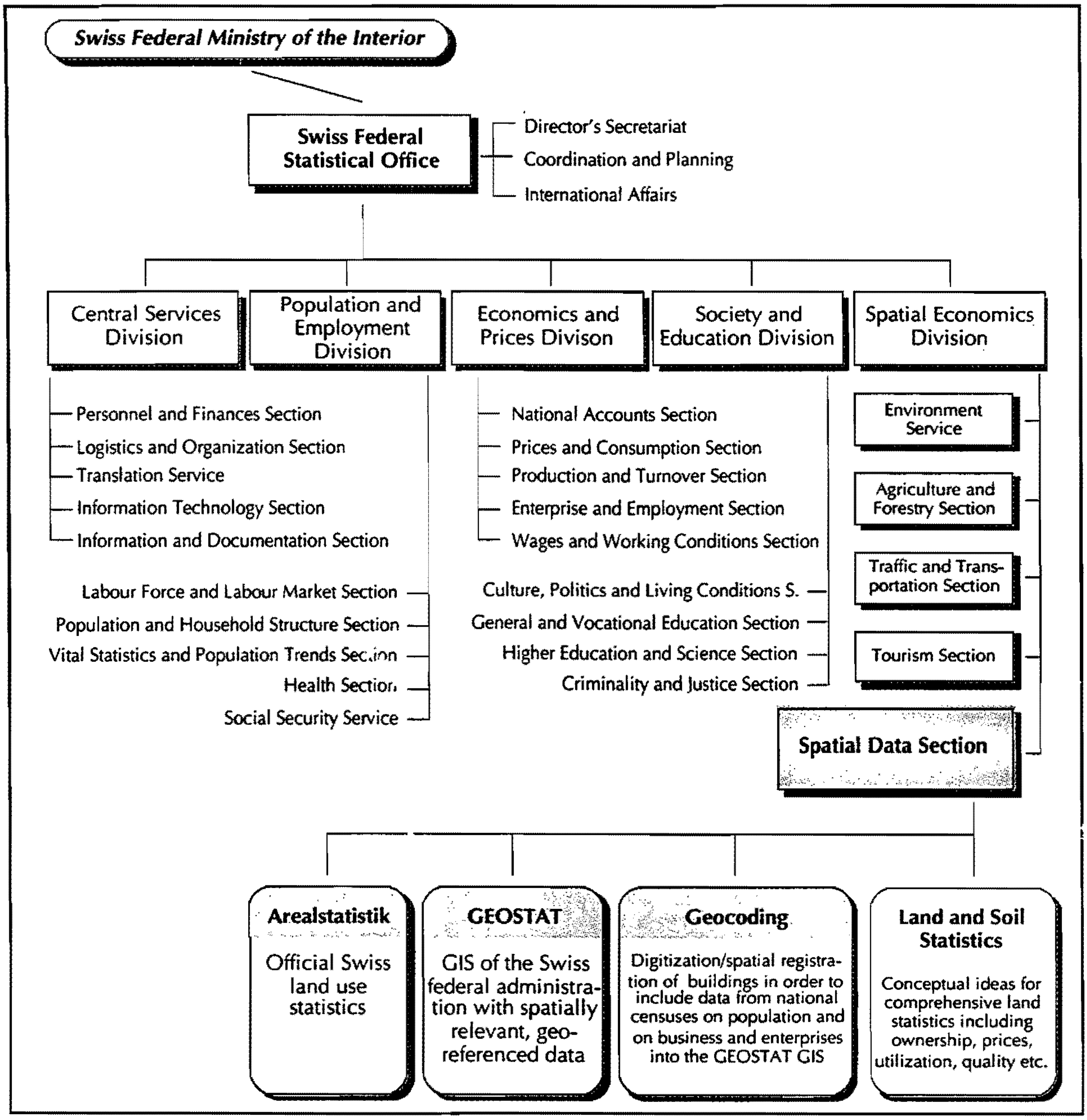

Swiss Federal Ministry of the Interior
Swiss Federal Statistical Office
Director's Secretariat
Coordination and Planning
International Affairs
Central Services Division
Population and Employment Division
Economics and Prices Divison
Society and Education Division
Spatial Economics Division
Personnel and Finances Section
Logistics and Organization Section
Translation Service
Information Technology Section
Information and Documentation Section
Labour Force and Labour Market Section
Population and Household Structure Section
Vital Statistics and Population Trends Section
Health Section
Social Security Service
National Accounts Section
Prices and Consumption Section
Production and Turnover Section
Enterprise and Employment Section
Wages and Working Conditions Section
Culture, Politics and Living Conditions S.
General and Vocational Education Section
Higher Education and Science Section
Criminality and Justice Section
Environment Service
Agriculture and Forestry Section
Traffic and Transportation Section
Tourism Section
Spatial Data Section
Arealstatistik
Official Swiss land use statistics
GEOSTAT
GIS of the Swiss federal administration with spatially relevant, geo-referenced data
Geocoding
Digitization/spatial registration of buildings in order to include data from national censuses on population and on business and enterprises into the GEOSTAT GIS
Land and Soil Statistics
Conceptual ideas for comprehensive land statistics including ownership, prices, utilization, quality etc.

Fig. 2 Organization and data flow model of GEOSTAT

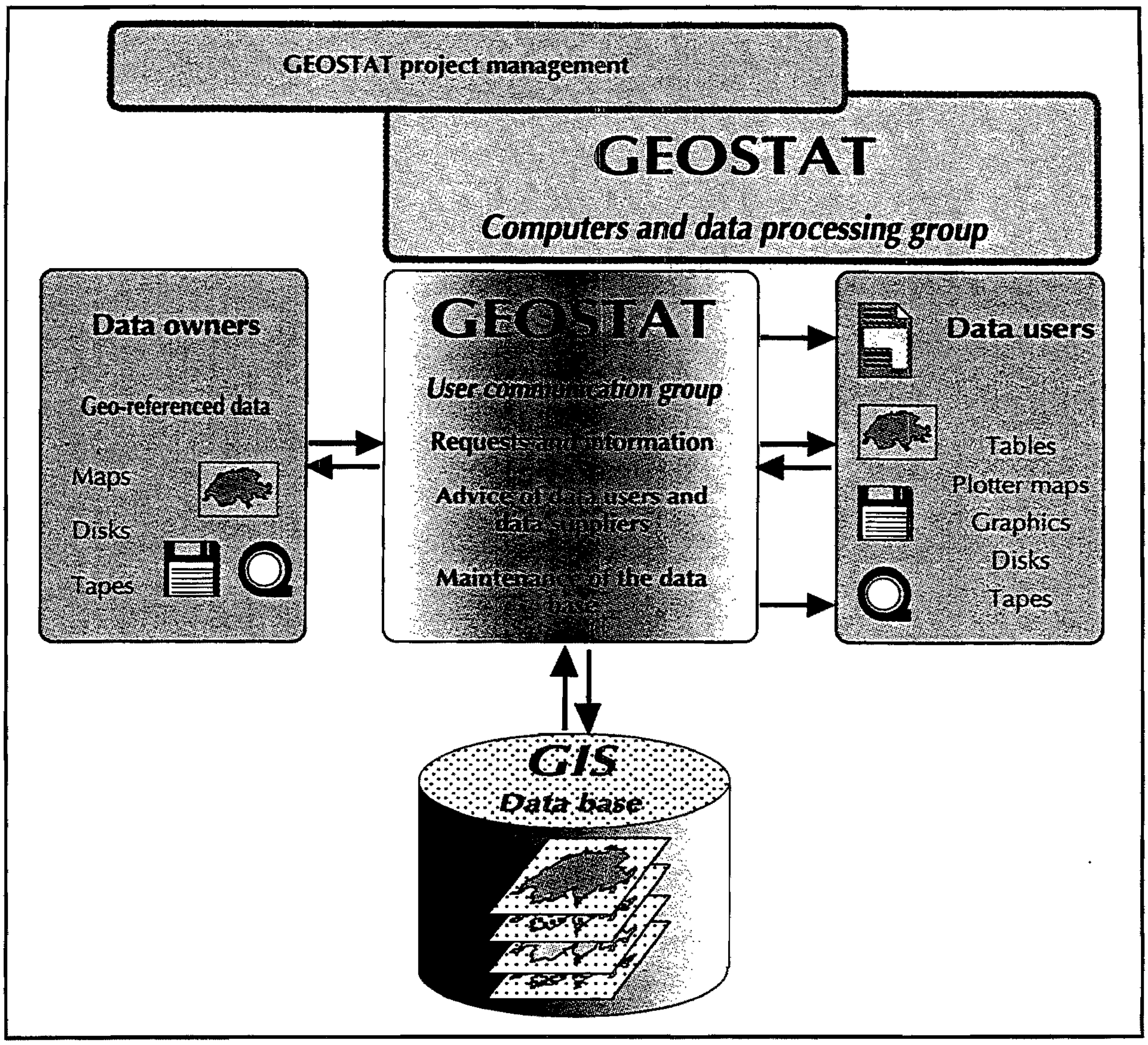


Fig. 3 Conflict between motorways and protected areas

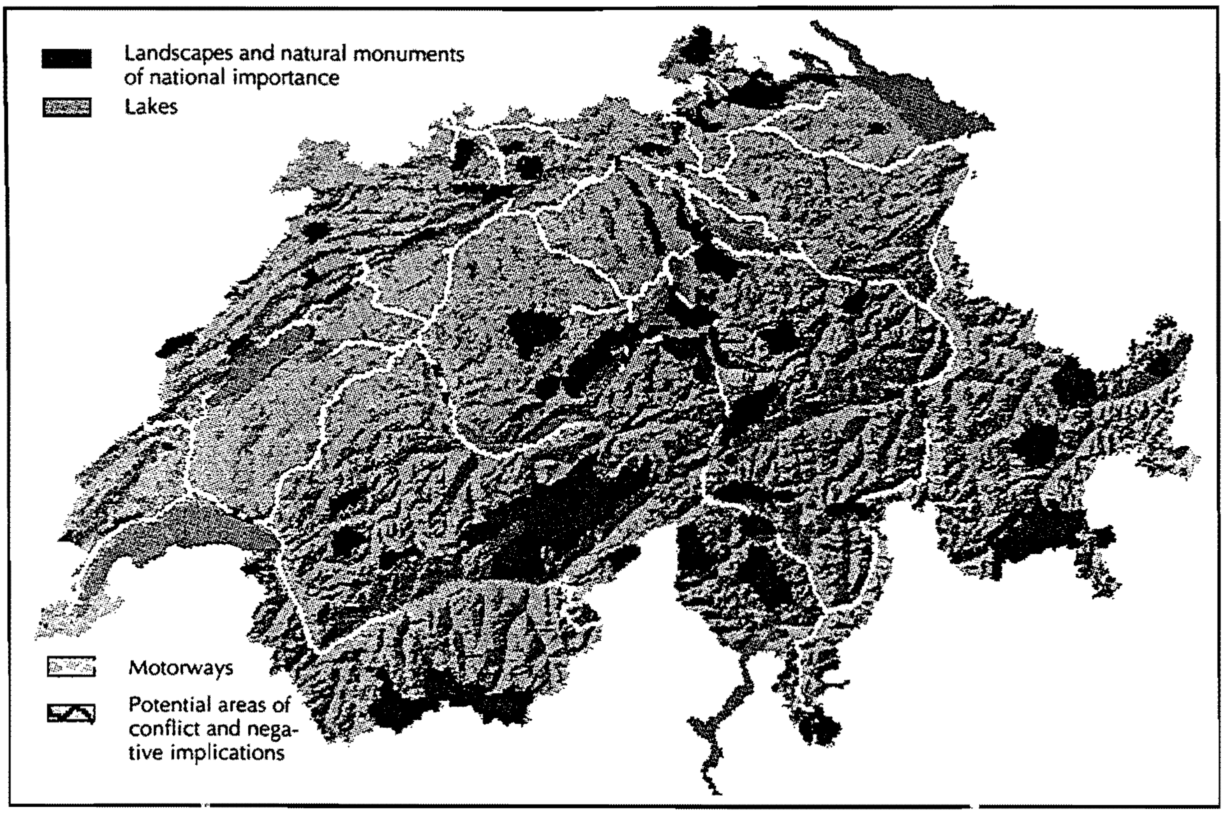
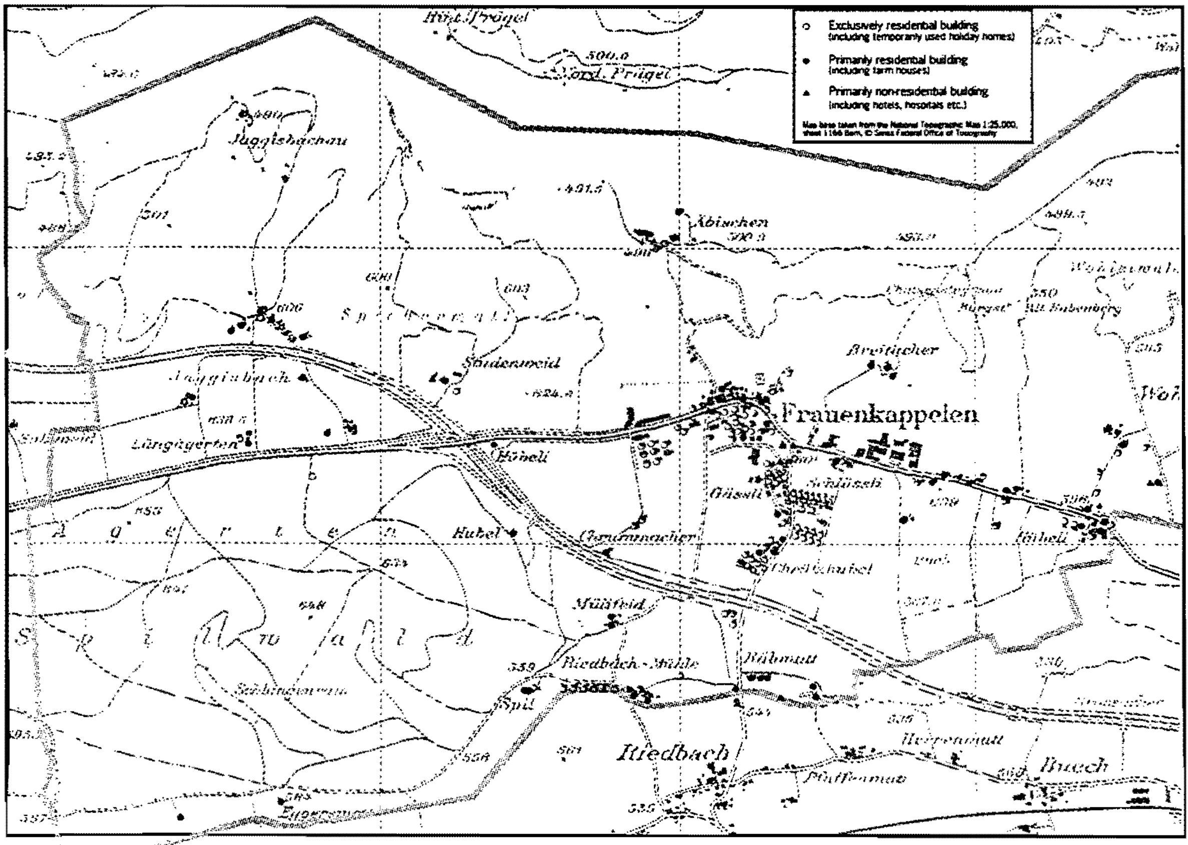

■ Landscapes and natural monuments of national importance
▨ Lakes
Motorways
Potential areas of conflict and negative implications

Fig. 4 Interpretion aid for the Swiss land use statistics 1992/97: building types according to national census of population and housing 1990

(Western part of Frauenkappelen commune, canton Bern)


○ Exclusively residential building (including temporarily used holiday homes)
● Primarily residential building (including farm houses)
▲ Primarily non-residential building (including hotels, hospitals etc.)
Frauenkappelen
Riedbach
Abischen
Breitacher
Höheli
Hubel
Müliteld
Riedbach-Mühle
Spil
Herrenmatt
Buch
Bühli
Jaggisbachau
Längägerten

Map base taken from the National Topographic Map 1:25,000, sheet 1166 Bern, © Swiss Federal Office of Topography

Fig. 5 Changes in land use and landscape around Baden, Switzerland

Disappearance of small aggregates

▨ Forest areas	★ Field fruit trees	126 ha
▭ Settlements, built-up areas	Field thickets, hedges	12 ha
	★ Isolated groups of trees	21 ha
	★ Wetlands	3 ha
	☒ New small aggregates	32 ha

Investigation based on the official Swiss land use statistics 1979/85 (data source from 1982) and a similar test based on aerial photographs of 1988

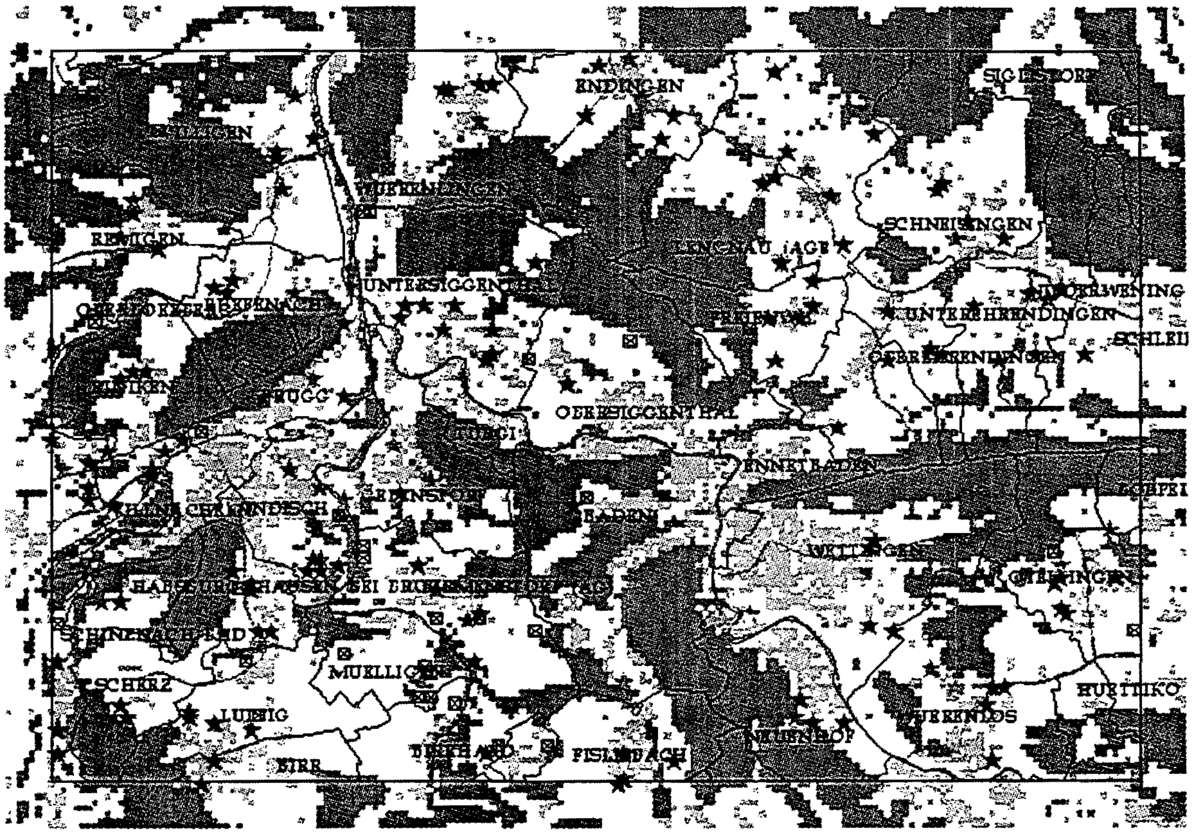
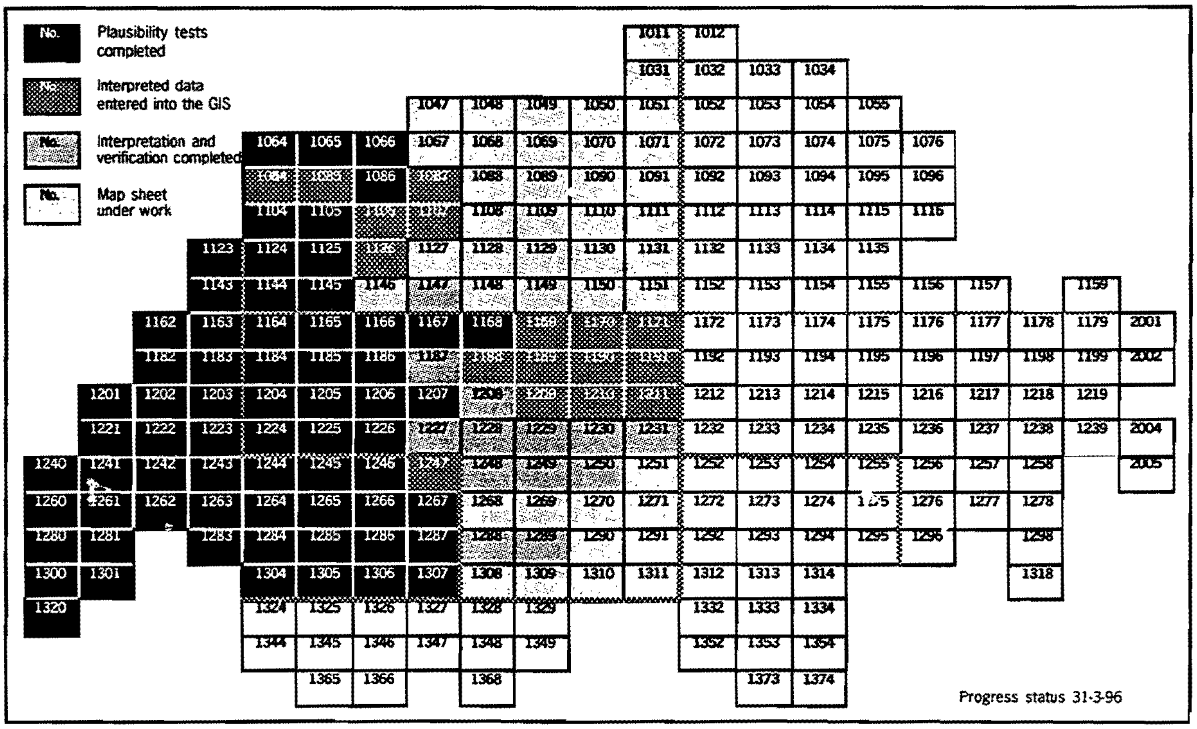


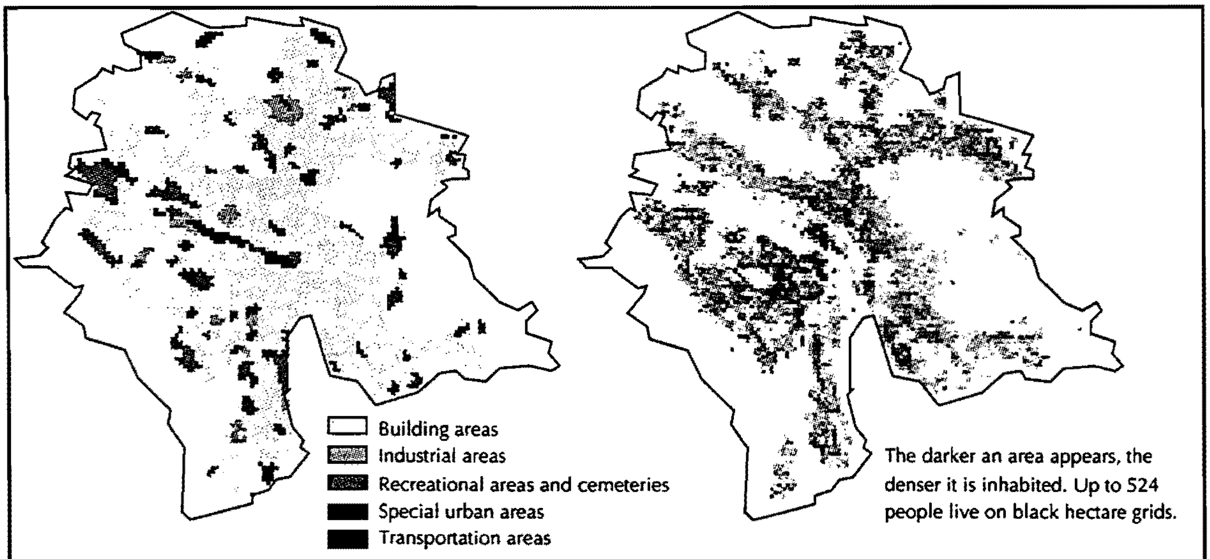
Fig. 6 Progress status of the Swiss land use statistics 1992/97



- ■ Plausibility tests completed
- ▩ Interpreted data entered into the GIS
- ▨ Interpretation and verification completed
- ☐ Map sheet under work

Progress status 31-3-96

Fig. 7: Presentation and visualization possibilities of population density and urban areas: example of the city of Zurich, Switzerland



☐ Building areas
▨ Industrial areas
▨ Recreational areas and cemeteries
■ Special urban areas
■ Transportation areas

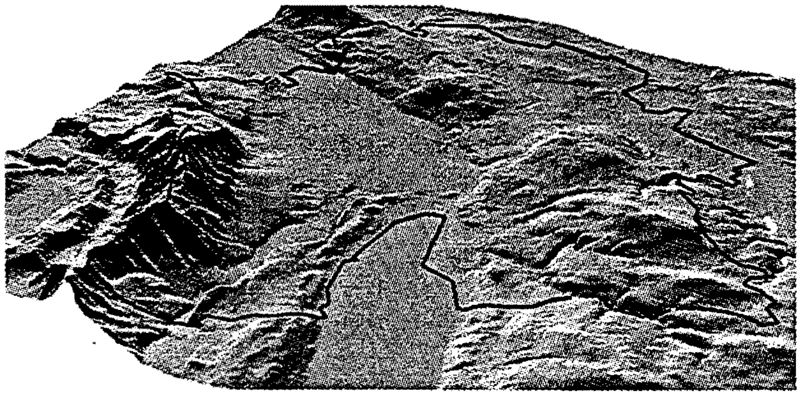
The darker an area appears, the denser it is inhabited. Up to 524 people live on black hectare grids.

Urban or built-up area of Zurich

Source: Swiss land use statistics 1979/85

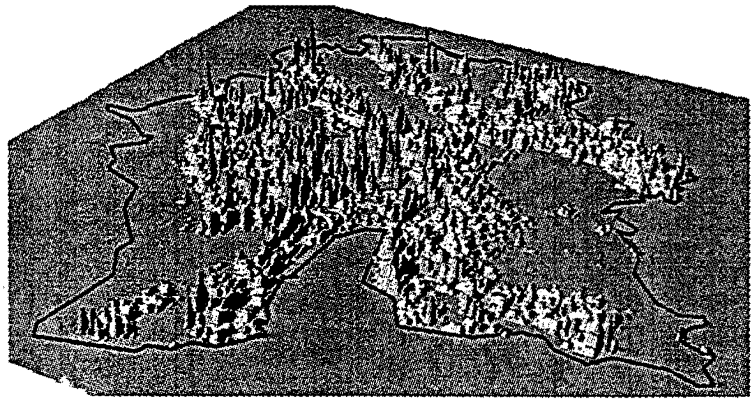
Population/inhabitants per hectare

Source: Swiss national census of population 1990



Natural terrain of Zurich, 3D view from SE

Source: GEOSTAT digital terrain model



Population/inhabitants per hectare, simulated 3D view from SE

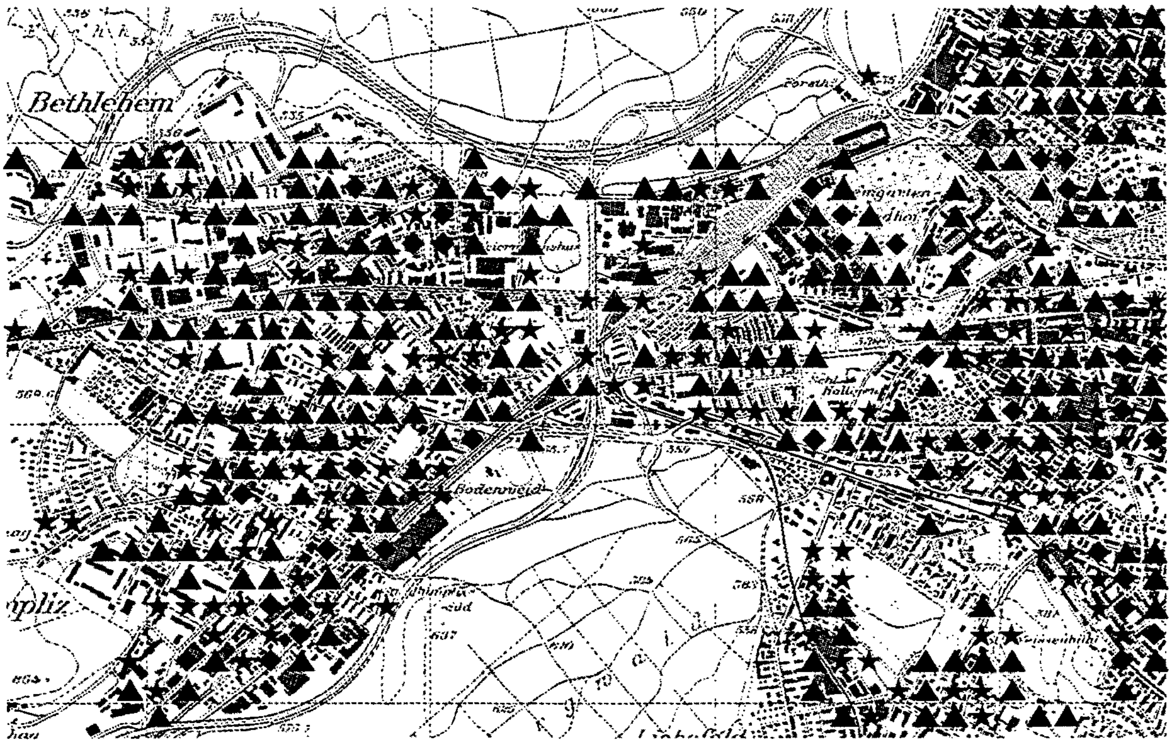
Source: Swiss national census of population 1990

Fig. 8 Employees according to economic sector (Bern–West, Switzerland)

★ more than 60% of employees per hectare in economic sector 2

▲ more than 60% of employees per hectare in economic sector 3

◆ 40–60% of employees per hectare in economic sectors 2 and 3



Map base taken from the National Topographic Map 1:25,000, sheet 1166 Bern, © Swiss Federal Office of Topography